INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-XXXX

Cerium Nitrate Technique for Decontamination of Gloveboxes

Deactivation and Decommissioning Focus Area

Prepared for
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INNOVATIVE TECHNOLOGY
Summary Report

Cerium Nitrate Technique for Decontamination of Gloveboxes

LAUR #03-4231

Deactivation and Decommissioning Focus Area

Demonstrated at
Los Alamos National Laboratory
Los Alamos, New Mexico

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Purpose of this document

Innovative Technology Summary Reports (ITSR) are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://www.em.doe.gov/ost under "Reports".

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SECTION 1
SUMMARY

Technology Summary

The U.S. Department of Energy (DOE) continually seeks effective and safer decontamination technologies for use in decontamination and decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area of the DOE's Office of Science and Technology sponsors large scale Demonstration and Development Projects (LSDDP's) in which developers and vendors of improved and innovative technologies showcase products that are potentially beneficial to DOE projects and to others in the D&D community. Benefits sought include reducing health and safety risks to personnel and the environment, increasing productivity, and decreasing the cost of operation.

The demonstration described in this ITSR was conducted at Los Alamos National Laboratory (LANL) to determine if decontamination using a cerium nitrate solution is an effective technique for removal of plutonium contamination from gloveboxes. Removal of this contamination will allow for gloveboxes to either be reused or classified as low-level waste (LLW). The decontamination technique involves the application of a 0.25 normal (N) cerium nitrate solution (in 1N nitric acid) onto the metallic surfaces of the glovebox. The radiological contaminants are removed by spraying the solution onto the surface, scrubbing it with an abrasive pad, and wiping it down with rags. Depending on the initial surface activity, several applications may be required to reduce contamination from transuranic (TRU) to LLW. This technique has been successfully used at the Rocky Flats Environmental Technology Site (RFETS) for the removal of glovebox contamination.

The demonstration at LANL included comparison of the cerium nitrate technique to a similar baseline technique in use at LANL. With the baseline technique, a dilute nitric acid solution was applied to the glovebox and scrubbed with an abrasive pad and rag to dissolve and remove actinides. In general, this technique also requires several applications to reduce the contamination from TRU to LLW levels. Figure 1 provides a photograph of the glovebox during the decontamination demonstration. Figure 2 shows the baseline method used to decontaminate the glovebox.

Figure 1
Photograph – Demonstration Glovebox Surfaces During Decontamination

Figure 2
Photograph - Demonstration of Cerium Nitrate Technique

Problem
The LANL waste inventory includes approximately 200 “legacy” TRU waste gloveboxes in temporary storage at Technical Area (TA)-54. These gloveboxes will be processed through the LANL Decontamination and Volume Reduction System to separate the LLW and TRU waste components. The LLW components will be disposed of in the LLW pits at TA-54, Area G. The TRU components will be packaged and certified for disposal at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. At this time, it is anticipated that the gloveboxes will have sufficient surface activity to be classified as TRU unless they can be decontaminated to LLW.

The disposal of waste items/components classified as TRU waste is costly, with an estimated cost of approximately $140,000 for an average sized glovebox. If the LANL gloveboxes can be decontaminated to LLW (i.e., < 100 nanocuries per gram [nCi/g]), the disposal cost will be reduced by 95 percent (%) to approximately $6,500. In addition to cost savings, decontamination may enable the reuse of gloveboxes that are not considered obsolete by design. It also may allow for other gloveboxes at LANL to be stored temporarily within the Plutonium Facility at TA-55 pending reuse. Finally, gloveboxes categorized as LLW with no future utility have an immediate path forward to disposition – they may be disposed of at approved LLW sites.

How It Works
Cerium nitrate (in acid) is a strong oxidizer capable of oxidizing and solubilizing plutonium and stainless steel components such as nickel, chrome, and iron. The solution is sprayed onto the surfaces, scrubbed in, allowed to react, and then rinsed with water. While reacting, the solution strips a very thin layer away from the metal surface of the glovebox which results in the removal of fixed radiological surface contamination.

Demonstration Summary

The cerium nitrate technique was demonstrated in September 2002 at the LANL TA-55 Plutonium Facility using a 17-year old, contaminated glovebox. The demonstration included decontamination of the glovebox floor by applying the cerium nitrate solution to one half and dilute nitric acid solution to the other half. Prior to conducting the demonstration, the inner surfaces of the glovebox were cleaned and wiped down with Fantastik™. All points measured on the glovebox surface registered more than one million counts per minute, which indicates surface activity higher than 2,857 thousand disintegrations per minute (kdpm) per 100 square centimeters (cm^2).

To be successful, the demonstration had to show a reduction of free and fixed contamination on all contacted surfaces to below 50 kdpm/100 cm^2. The operation times from start to finish of each task, alpha survey measurements for surface activity, and waste volumes generated during the demonstration were recorded.

The demonstration provided the following results:

- Two workers conducted the decontamination demonstration for the floor of a 137 cm (54 in) x 114 cm (45 in) x 76 cm (30 in) glovebox.
- Five decontamination cycles were conducted using both the cerium nitrate and nitric acid solutions with the following results:
  - Cerium nitrate solution reduced the contamination to 50 kdpm/100 cm^2 at all survey locations except for two spots located in the left middle and lower portions of the glovebox floor. An average reduction in surface activity over the entire surface for each decontamination cycle was calculated and resulted in a drop from more than 2857 kdpm/100 cm^2 to 90 kdpm/100 cm^2. It was estimated that the equivalent of one more decontamination cycle would be required to reach the 50 kdpm/100 cm^2 target.
  - Nitric acid solution reduced the overall actvitiy of the glovebox floor but was incapable of reducing the contamination level to below 50 kdpm/100 cm^2 at any single survey location after 5 decontamination cycles. An average reduction in surface activity over the entire surface for each decontamination cycle was calculated and resulted in a drop to 104-kdpm/100 cm^2. It was estimated that the equivalent of four more decontamination cycles would be required to reach the 50 kdpm/100 cm^2 target.
- The demonstration for each technique produced approximately 0.014 m^3 (0.5 ft^3) of waste (i.e., spray bottles, damp polypropylene rags, Scotchbrite pads) while decontaminating 5.6 ft^2.
- The cost for each technology on a square meter basis is as follows:
  - Cerium nitrate = **$8,114.13**/m^2 (**$753.45**/ft^2) for six decontamination cycles
  - Nitric acid = **$11,857.60**/m^2 (**$1,101.06**/ft^2) for nine decontamination cycles

NOTE: These costs are based on decontamination of the glovebox floor only, which is typically the most contaminated of all glovebox surfaces. Extrapolation of these costs to a whole glovebox internal surface area should not be performed, since results may be unrealistically high compared to other decontamination demonstrations.

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Other
All published Innovative Technology Summary Reports are available on the OST Web site at http://www.em.doe.gov/ost under "Reports". The Technology Management System (TMS), also available through the OST Web site, provides information about OST programs, technologies, and problems.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

The cerium nitrate technique has been previously used elsewhere to decontaminate tanks and was developed at the RFETS for glovebox decontamination. It is not restricted by a patent or owned by any corporation. The concentration (0.25 normal [N] cerium nitrate in 1N nitric acid), and time (20 minutes) was determined after thorough compatibility studies conducted at RFETS prior to implementation as a decontamination technique.

The technique uses oxidation/reduction reactions:
Cerium nitrate solubilizes plutonium present on or in the metal surface imperfections of the glovebox by reacting with tetravalent plutonium oxide (Pu [IV]) according to the following reaction:

$$2Ce(IV) + Pu\ (IV) \rightarrow 2Ce(III) + Pu(VI)$$

It also reacts with the major components of stainless steel (i.e., iron, chromium, and nickel) according to three additional reactions:

$$3Ce(IV) + Fe \rightarrow 3Ce(III) + Fe\ (III)$$
$$3Ce(IV) + Cr \rightarrow 3Ce(III) + Cr\ (III)$$
$$2Ce(IV) + Ni \rightarrow 3Ce(III) + Ni\ (III)$$

System Operation

Cerium nitrate is mixed into nitric acid to form a 0.25N solution. The solution is then transferred into a spray bottle and sprayed onto the metal surfaces of the glovebox and scrubbed in using an abrasive pad. After being scrubbed, the solution is allowed to remain on the surface for approximately twenty minutes. The cerium nitrate solubilizes plutonium present on or in the metal surfaces of the glovebox using oxidation/reduction reactions as described above. The solution also reacts with the major components of stainless steel removing the top layer from the surface. After twenty minutes, the solution is rinsed with water and is removed from the surface. It is recommended that a carbonate or similar solution also be used to rinse the surface a second time and react with any cerium nitrate that remains.

SECTION 3
PERFORMANCE

Demonstration Plan

Background/Site Description

The demonstration was conducted at the LANL Technical Area 55 (TA-55) using a glovebox that measured 137 cm (54 in) long, 114 cm (45 in) high and 76 cm (30 in) deep and was constructed of 0.48 cm (3/16 in) thick 316L stainless steel (Figure 3), with a total surface area of approximately 7m^2 (75 ft^2). The glovebox included two viewing windows on the front wall (52 cm [20.5 in] long by 29 cm [11.5 in] wide) and two chest windows located between each set of gloves (14 cm [5.5 in] long by 23.5 cm [9.25 in]wide). The gloveports were 15 cm (6 in) in diameter and contained Hypalon 15 mil gloves on the lower stations and 60 mil gloves on the upper stations. The equipment for the demonstration was introduced into the glovebox through 48 cm (19 in) doors located on the right and left sides. The glovebox atmosphere consisted of dry air.

Figure 3
Demonstration Glovebox

The glovebox was in service at TA-55 for approximately 17 years and was used to carry out analytical chemistry functions involving actinide solutions in nitric, oxalic, and hydrofluoric acid. Prior to the demonstration, the glovebox inner surfaces were wiped down with Fantastic™ to remove dirt and other residues. The glovebox floor was surveyed at six points to establish an initial surface contamination level. All points measured showed an activity above one million counts per minute (2,857 kdpm/100 cm^2). A Ludlum Model # 139 gas proportioned alpha counter was used during the demonstration to measure the alpha activity following each decontamination cycle for both the innovative and baseline technologies.

Objectives

The purpose of the demonstration conducted at LANL was to evaluate the cerium nitrate decontamination performance in comparison to the baseline technology, nitric acid decontamination. The following objectives were considered in the comparison:

- Decontamination Performance – The technique's ability to remove radioactive contamination from the glovebox surface to such a level that that it could be recycled, reused or disposed of as LLW. For this demonstration 50 kdpm/100 cm^2 was used as the decontamination objective for all points on the floor.

- Feasibility – Based on the large surface area to be decontaminated, the innovative technique should be less labor intensive, less difficult to handle, or less difficult to automate than the baseline technology.

- Safety – The innovative technology or technique should not increase the risk to workers through increased exposure time to radioactive or chemical hazards.

- Waste Minimization – The method should not create large quantities of secondary waste. Any waste generated must have a path forward to disposal (i.e., LLW, TRU or TRU).

- Cost-Effectiveness – The method should compare favorably to the baseline technology costs.

Procedure

The demonstration was conducted according to the following procedures:

1. Prepare the 0.25N cerium nitrate solution, the 0.5N nitric acid solution, and rinse water in separate 1 liter (L) spray bottles. Load into the glovebox along with abrasive pads (Scotch-Brite) and polypropylene rags.
2. Identify a centerline on the glovebox floor which defines two halves of approximately 0.52 m^2 (5.6 ft^2) each.
3. Spray a light coating of 0.25N cerium nitrate solution on one half of the glovebox. Work it into the surface using an abrasive pad.
4. Spray a light coating of 0.5N nitric acid solution on the other half of the glovebox. Work it into the surface using an abrasive pad.
5. Leave both solutions on the glovebox floor for twenty minutes.
6. Spray with water to rinse.
7. Remove the water and solution using a squeegee and polypropylene rags. Dry/polish the floor using a polypropylene rag.
8. Survey to glovebox floor for residual surface contamination.
9. Repeat steps 1-8, as necessary.

Data collected during the demonstration included alpha activity, labor hours to mobilize, labor hours to apply and remove the solutions, labor hours to demobilize, the volume of acid solutions used, and the number of rags necessary to complete the demonstration.

Results

Decontamination Performance

The demonstration was limited to decontamination of the glovebox floor. It took approximately 8 hours to complete and included a total of 5 decontamination cycles using both the cerium nitrate and nitric acid techniques. During each decontamination cycle, 150 milliliters (mL) of each solution were applied to one half of the glovebox floor. This volume of liquid adequately covered the glovebox surface without running out of the test area.

Innovative Technology
Table 1 shows the surface activity results for the cerium nitrate decontamination cycles. The cerium nitrate reduced the contamination on the glovebox floor to 50 kdpm/100 cm^2 at all survey locations except for two spots located in the left middle and left lower portions of the floor. The first cycle of decontamination resulted in a decontamination factor (defined as initial activity/final activity) of approximately 7.9. The remaining decontamination cycles resulted in decontamination factors ranging from 1.2 to 1.8.

Table 1
Results – Cerium Nitrate Decontamination Cycles

Glovebox Surface	Surface Activity (kdpm/100 cm^2)					
	Initial	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Left Upper	>2857	275	150	125	75	35
Left Middle	>2857	600	500	350	250	245
Left Lower	>2857	600	450	125	125	125
Right Upper	>2857	150	75	75	35	35
Right Middle	>2857	275	200	125	75	50
Right Lower	>2857	275	175	75	75	50
Glovebox Ave	>2857	362	258	146	106	90
Decontamination Factor (Ave.)	-	7.9	1.4	1.8	1.4	1.2

Figure 4 provides a graph that shows the drop in surface activity for each survey location associated with the cerium nitrate decontamination cycles.

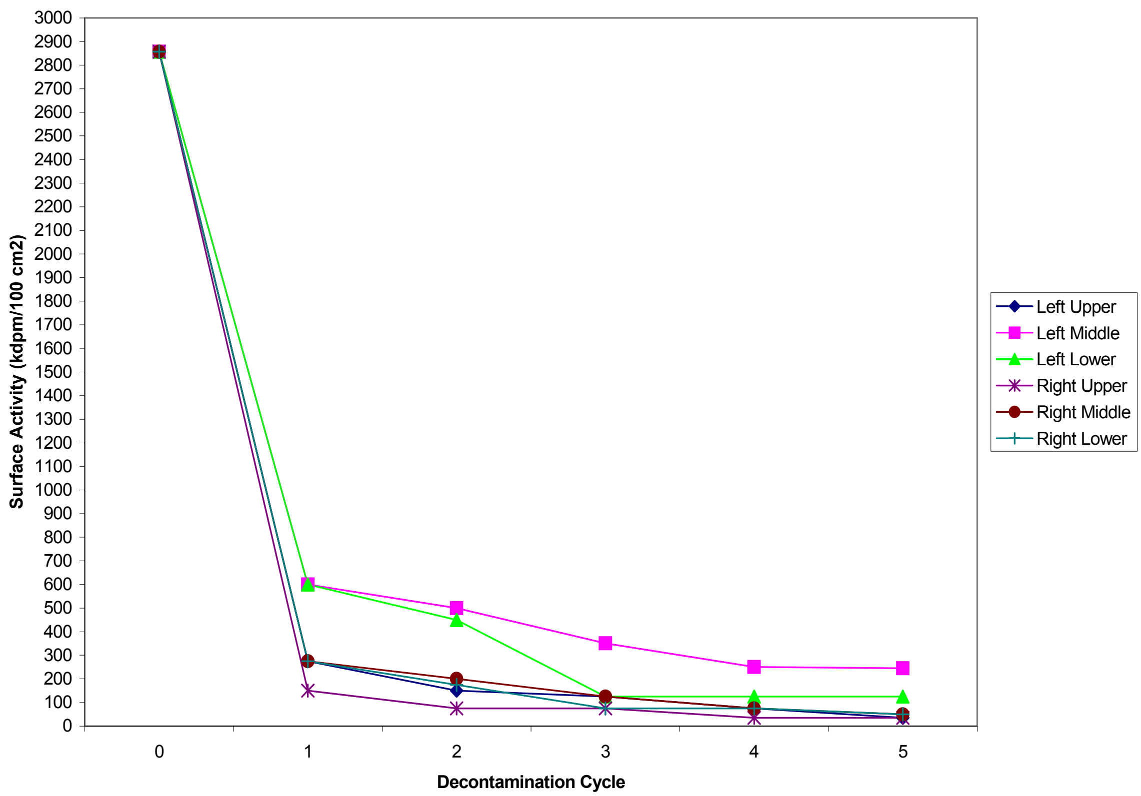

Figure 4
Decontamination Results for Cerium Nitrate Solution

An average drop in surface activity was calculated for the cerium nitrate portion of the demonstration and resulted in a drop from 2,857 kdpm/100 cm^2 to 90 kdpm/100 cm^2. Additional decontamination at the hot spots identified at the left middle and lower locations of the glovebox floor would allow for the surface to achieve an average surface activity below 50 kdpm/100 cm^2. However, due to time constraints, additional decontamination cycles were not conducted. It is estimated that applying the equivalent of one additional decontamination cycle (i.e., 6 total cycles) would achieve this target surface activity.

Baseline Technology
Table 2 shows the surface activity results for the nitric acid decontamination cycles. The nitric acid solution reduced the overall activity of the glovebox floor but was incapable of reducing the contamination level to below 50 kdpm/100 cm^2 at any single location after 5 decontamination cycles. The first cycle of decontamination resulted in a decontamination factor of approximately 12.9. The remaining decontamination cycles resulted in decontamination factors from 1.1 to 1.4.

Table 2
Results – Nitric Acid Decontamination Cycles

Glovebox Surface	Surface Activity (kdpm/100 cm^2)					
	Initial	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Left Upper	>2857	375	175	125	125	125
Left Middle	>2857	125	125	125	125	100
Left Lower	>2857	150	100	100	75	75
Right Upper	>2857	225	225	215	200	125
Right Middle	>2857	200	200	175	125	75
Right Lower	>2857	250	250	245	200	125
Glovebox Ave	>2857	221	179	164	142	104
Decontamination Factor (Ave)	-	12.9	1.2	1.1	1.2	1.4

Figure 5 provides a graph that shows the drop in surface activity for each survey location associated with the nitric acid decontamination cycles.

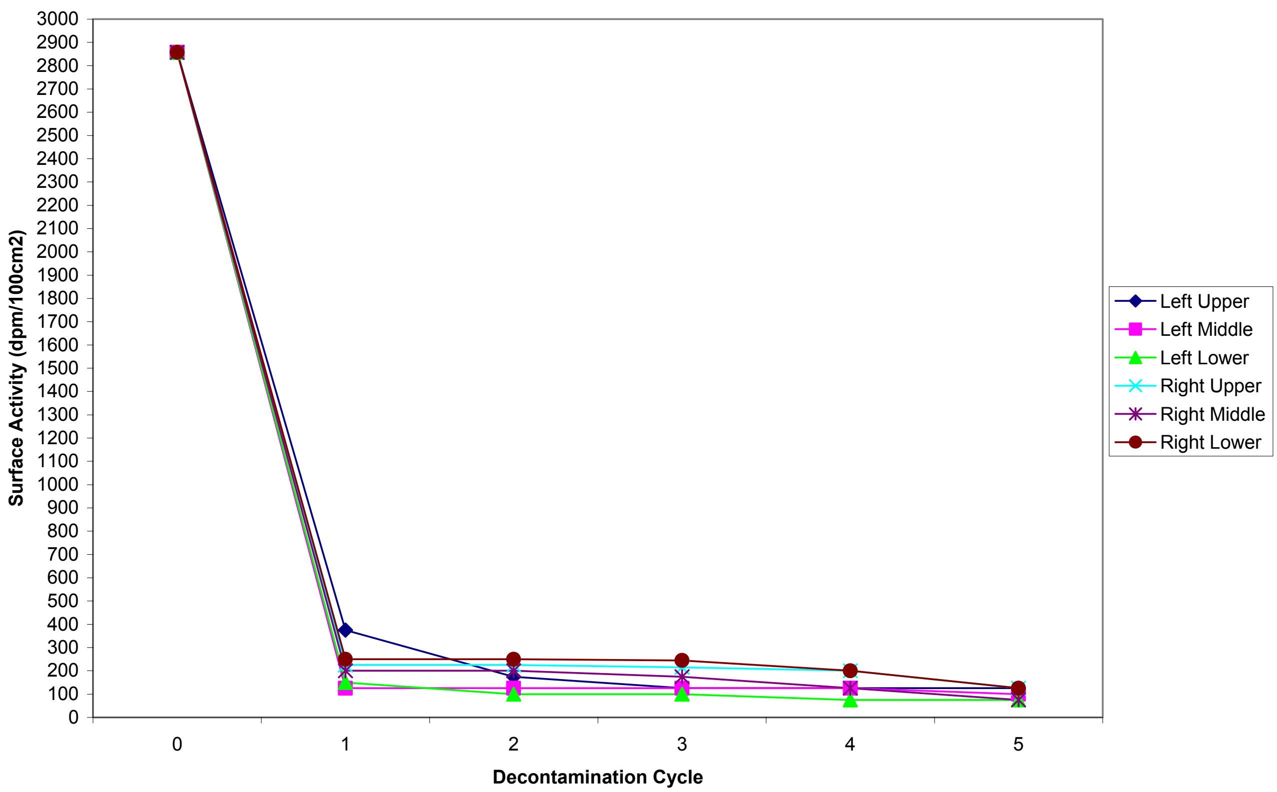

Figure 5
Decontamination Results for Nitric Acid Solution

An average reduction in surface activity was calculated for the nitric acid portion of the demonstration and resulted in a drop from 2,857 kdpm/100 cm^2 to 104 kdpm/100 cm^2. In order to achieve 50 kdpm/100 cm^2 at any single location on the glovebox floor, it is estimated that 4 additional decontamination cycles (i.e. 9

total cycles) would be required. However, due to time constraints, additional decontamination cycles were not conducted.

Comparison

Figure 6 provides a graph that illustrates a comparison of the innovative and baseline techniques described in this ITSR. The cerium nitrate technology performs slightly better, over the course of several decontamination cycles, than the nitric acid technology, with a slightly better removal capability during additional applications. It is not clear why the cerium nitrate technology did not perform as well as the the nitric acid technology during the first cycle. On the other hand, it is clear that the more aggressive chemistry of cerium nitrate performs better in subsequent decontamination cycles.

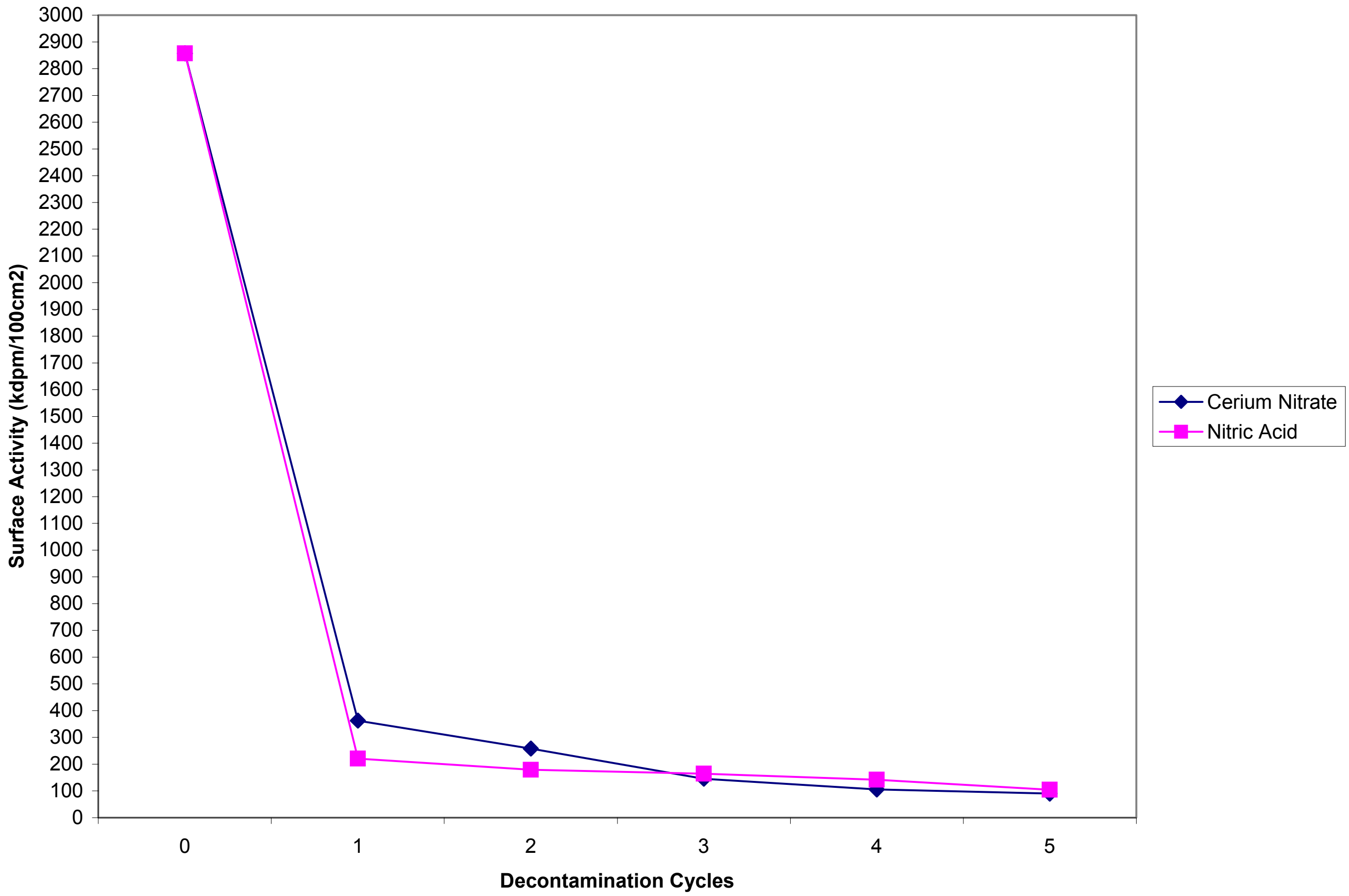

Figure 6
Average Removal of Surface Activity for Cerium Nitrate and Nitric Acid

Feasibility

The cerium nitrate technique is feasible and comparable to the nitric acid baseline technique. Two problems, however, were encountered during the demonstration which applies to both technologies. First, it was difficult to physically reach all of the interior surfaces. Further experimentation is recommended to perfect the mechanical means (extension sticks, grippers, etc.) of reaching all interior surfaces with enough leverage to apply scrubbing force. Second, the technicians reported that the rinsing and drying process is labor intensive and fatiguing. It is recommended that individual workers alternate between the rinsing and wiping tasks.

Waste Minimization

The cerium nitrate technique does not reduce the quantity of waste generated during decontamination as compared to the baseline technology on a per cycle basis. However, waste reduction does occur because more decontamination cycles are required with the baseline technology to reach the target surface activity level. Table 3 provides a list of all the wastes produced during the demonstration.

Table 3
Waste Stream Descriptions and Quantities for Cerium Nitrate and Nitric Acid Decontamination Technologies

Waste Description	Each technique (quantity – 5 cycles demo)	Cerium Nitrate (quantity – 6 cycles est.)	Nitric Acid (quantity – 9 cycles est)
Decontamination Solution	750 mL	900 mL	1350 mL
Abrasive Pads (Scotch-Brite)	5	6	9
Polypropylene Rags	10	12	18
Totals m^3 (ft^3) for ½ floor (0.52 m^2)	0.0716 (2.53)	0.0859 (3.04)	0.129 (4.55)
Unit Area Volume m^3/m^2 (ft^3/ft^2)	0.138 (0.45)	0.165 (0.54)	0.248 (0.81)

mL = milliliters

Safety

The cerium nitrate technique did not significantly impact the radiological exposure to each worker on a per cycle basis. It took approximately the same amount of time to introduce equipment to the glovebox, apply the decontamination solution, rinse and dry the surfaces, and survey the decontaminated area for both the cerium nitrate and nitric acid techniques. However, reduced exposure time to the glovebox environment will result with cerium nitrate due to the reduced number of cycles required to reach the target surface activity level. Table 4 provides the time associated with each of the activities necessary to complete decontamination of 0.52 m^2 (5.6 ft^2) of the glovebox floor with each technique.

Table 4
Estimated Glove Time for Decontamination Using Cerium Nitrate and Nitric Acid

Decontamination Activity	Activity Time per Cycle	Total Time (min) Cerium Nitrate (6 cycles) est.	Total Time (min) Nitric Acid (9 cycles) est.
Introduction of Materials	10	60	90
Apply/Scrub Solution	5	30	45
Residence Time (no gloves)	20	120	180
Remove Solution/Dry Surface	15	90	135
Survey	15	90	135

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

The primary competing technologies/techniques are briefly described below:

- **CO_2 Pellet Process** – A process that utilizes small, solid carbon dioxide particles propelled by dry compressed air. The CO2 particles shatter upon impact with a surface and flash into dry CO_2 gas. Decontamination is accomplished when the CO_2 particles shatter upon impact with the surface and flash dry into CO_2 gas. The rapidly expanding CO_2 gas lifts and flushes the contamination. Contamination and materials are then either captured by a HEPA filter or removed using HEPA-filtered vacuum cleaners. Advantages include:
  - Time ~ 4 hours (1.22 m [4 ft] x 1.22 m [4 ft] x 0.91 m [3 ft] glovebox)
  - No Secondary Waste
  - No scrubbing (not labor intensive)
  - Minimizes radiation exposure to workers
  - Reliable technology

- **High Pressure Water Process** – Consists of a high-pressure water pump and a specially made gun-type water jet-cleaning tool. All moving parts are enclosed within removable protective covers for operator safety. An eleven horse power electric motor along with a triplex pump is used to achieve and maintain normal working water pressures from 5000- 40,000 psi. Incoming water is dual filtered to removed particles larger than 0.5 microns. Advantages include:
  - Time ~ 4 hours (1.22 m [4 ft]x 1.22 m [4 ft] x 0.91 [3 ft] cm glovebox)
  - Removes coatings including multiple layers of paint.
  - No scrubbing (not labor intensive).
  - Minimizes radiation exposure to workers.
  - Reliable technology.
  - Patents/Commercialization/Sponsor

- **LANL Electrolytic Decontamination** – This closed loop cleaning system, which is similar to the commercial process of electropolishing, achieves an electrolyte etch at low direct currents and voltages (40mA/cm^2 and 3-10VDC) with a solution of water and sodium nitrate. The unit consists of a detachable hand fixture, solution reservoir, pump, ultra-filtration module, vacuum pump, pH controller with electrode, pH control pump with tank, and stand. The unit operates by connecting the negative lead to the glovebox and the positive lead to the hand fixture. As the solution flows through the hand fixture, a thin layer of metal is rapidly stripped away, removing surface contamination along with it. For additional information see ITSR OST/TMS ID #3235. Advantages include:
  - High decontamination factors – as high as 20 in one pass; up to 500 in two passes.
  - No liquid waste generated
  - Minimal solid waste generated
  - No scrubbing required
  - Reliable, proven technology

- **Commercial Three Step Technology** – Decontamination solutions and/or service available from Environmental Alternatives Inc. which involves the application and removal of custom formulated, proprietary solutions. Each solution is applied in low volumes, usually as a spray, left to set for a defined time, rinsed clean, and then removed.

  Advantages include:
  - Available as a contracted service
  - Can be formulated for use on a variety of materials

Technology Applicability

The following five attributes must be true for a glovebox decontamination technique to be considered effective:

- Easy to apply while working in glovebox gloves.
- Capably of removing both smearable and fixed contamination from the surfaces. Ideally from TRU levels to below LLW acceptance criteria.
- Produce minimal waste that has a path forward,
- Reduce the time workers spend working in the glovebox, limiting both fatigue and exposure.
- Cost effective.

The cerium nitrate technique is comparable to the nitric acid technique with respect to application, waste production, and cost effectiveness. Its applicability lies in its capability to remove more contamination per cycle as shown in this demonstration. This meets for the objective of reducing contamination levels to low-level without increasing secondary waste while reducing worker exposure due to the reduced number of decontamination cycles required.

Patents/Commercialization/Sponsor

There are no patents required to use cerium nitrate decontamination technique.

SECTION 5
COST

Methodology

The objective of the cost analysis is to provide interested parties with a cost estimate for implementation of the cerium nitrate decontamination technology at DOE sites. This cost estimate considers the costs associated with both techniques on a unit area basis.

The baseline and innovative techniques were demonstrated at LANL under controlled conditions (i.e., an in-place glovebox floor) to facilitate observation and typical duration of procedures. To approach realistic implementation costs, additional assumptions were invoked regarding the cost comparison with the baseline technology. This cost analysis compares both technologies based on a unit processing cost.

Key assumptions for the cost estimate/cost comparison are listed below. Other assumptions and details about the cost analysis are presented in Appendix B.

- For the demonstration, each technique was applied five times to decontaminate one half of the glovebox floor (0.52 m^2 [5.6 ft^2]). To arrive at comparative implementation costs for each technology, the time and material costs required to apply each technique were extrapolated to account for six and nine cycles required to achieve the target decontamination levels. These costs were then normalized to a unit square meter for each technology.
- It is assumed that two technicians will carry out the work.
- No overhead factors were applied to other direct costs.
- Fully burdened labor rates for LANL personnel (at TA-55 PF4) were used in the estimate.
- Gloveboxes are assumed to be free of equipment, and no other cost to clean or move equipment out of the glovebox will be included.
- No additional procedural costs were involved.

Cost Analysis

To develop an estimate for implementation, a cost per square meter basis was chosen. Activities were grouped under higher level work titles per the work breakdown structure shown in *Hazardous Toxic, Radioactive Waste Remediation Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS) (U.S. Army Corps of Engineers, 1996).

Estimates were developed for mobilization, sampling and testing, demobilization and disposal costs for the innovative technology and the baseline technology. While the demonstration times in Table 4 were used as a basis, the following assumptions were incorporated into the estimates:

a. "Residence Time" was not included as a separate activity because the solution would remain in place at least 20 minutes if an entire glovebox were being decontaminated.
b. Survey times were not scaled up in a linear manner, based on experiences with other similar decontamination demonstrations. See Appendix B for further discussion.

The total costs for decontaminating the glovebox floor were estimated to be \$4,219.35 using the cerium nitrate technique and \$6,165.95 using the nitric acid (baseline) technique. These costs translate to **\$8,114.13/m^2 (\$753.45/ft^2)** for cerium nitrate and \$**11,857.60/m^2 (\$1,101.06/ft^2)** for nitric acid.

NOTE: These costs are based on decontamination of the glovebox floor <u>only</u>, which is typically the most contaminated of all glovebox surfaces. Extrapolation of these costs to a whole glovebox internal surface area should not be performed, since results may be unrealistically high compared to other decontamination demonstrations.

Figure 7 compares the implementation costs for both techniques. The mobilization cost for the cerium nitrate is greater than that of the nitric acid because of the cost of solution (Equipment/Materials). The application time for the cerium nitrate is higher when applied only once to the glovebox, however, an increase in the application time will be required to conduct the additional applications of nitric acid in order to match the decontamination effectiveness of the cerium nitrate. The demobilization cost is less than that of the nitric acid solution (baseline) because fewer applications are required. Waste disposal costs are also reduced because less material is required to reduce the contamination levels to target levels.

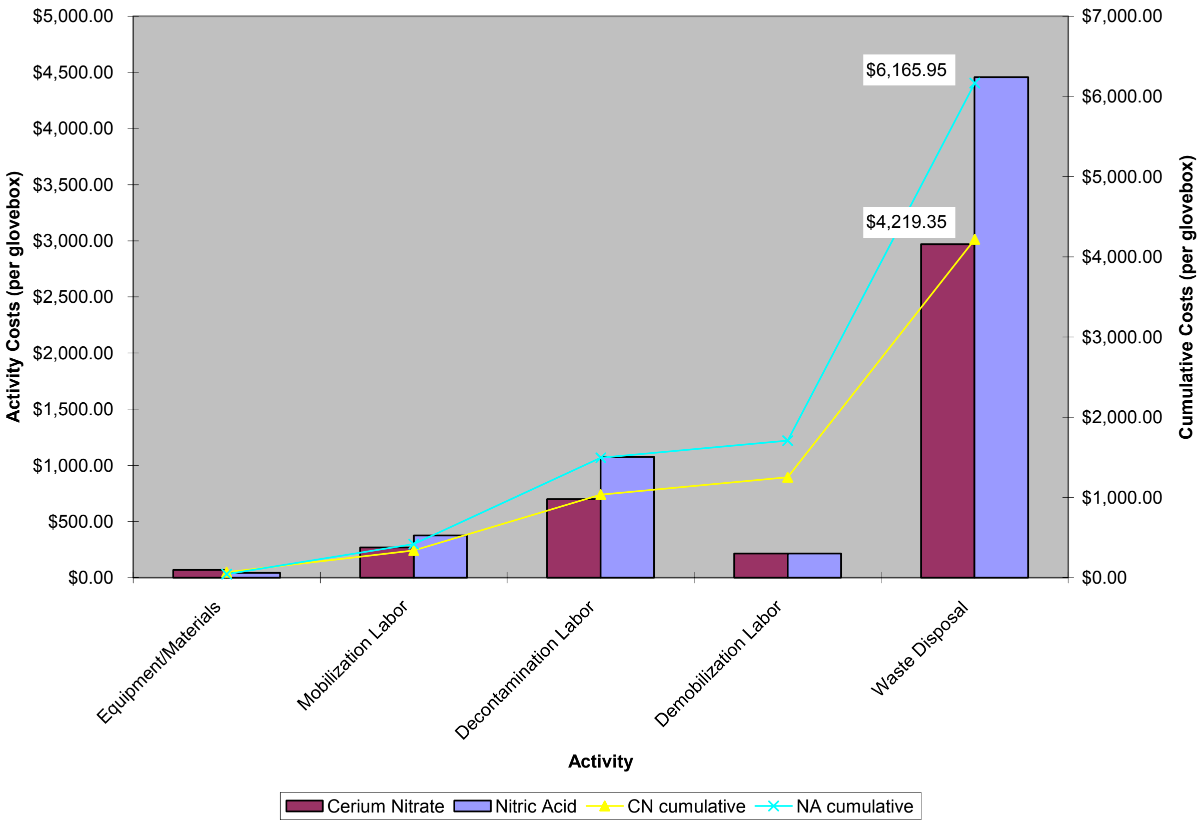

Figure 7
Costs for Glovebox Floor Decontamination with Cerium Nitrate and Nitric Acid

Cost Conclusions

The cost estimate provides a reasonable cost for implementation of cerium nitrate decontamination technique (innovative technology) at a DOE site. The cost for each technology on a square meter basis is approximately **$8,114.13/m^2** (\$753.45/ft^2) for the innovative cerium nitrate technique and approximately **$11,857.60/m^2** (\$1,101.06/ft^2) for the baseline nitric acid technique. Therefore, the cost of the innovative technology is approximately 32% less than the cost of the baseline technology to achieve similar results.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

Regulations for using the cerium nitrate decontamination technique are dependent upon each site's accepted waste regulations.

Safety, Risks, Benefits, and Community Reaction

Worker Safety
Workers must be trained in the proper procedures for glovebox work, and chemical handling safety. Glovebox materials must be chemically compatible with the solutions.

Community Safety
Community safety is not adversely affected by using cerium nitrate solutions to decontaminate gloveboxes. The system will not significantly increase the background radiation in an area. Transportation of the unit poses no risk to the public.

Environmental Impact
There is no negative impact and a potential positive impact to use of the system since it has the capability to dramatically reduce contamination levels on metallic objects before they are disposed.

Socioeconomic Impacts and Community Reaction
There are no socio-economic impacts associated with using cerium nitrate to decontaminate gloveboxes. Community reaction is likely to be positive since less actinide waste will be disposed of.

SECTION 7
LESSONS LEARNED

Implementation Considerations

The demonstration at LANL indicated positive results for decontamination of the floor in one particular glovebox. Every effort was made to provide a comparable test, therefore one can expect cerium nitrate to perform better in similar applications. No two gloveboxes can be expected to have the same level or makeup of contamination, so results may vary.

Technology Limitations and Needs for Future Development

The cerium nitrate demonstration conclusively proved that it successfully decontaminated the test glovebox. It provides DOE a simple means of reducing contamination levels within gloveboxes so that they can be reused or disposed of. The technicians had the following comments and recommendations regarding the ergonomics of using this process within a glovebox.

- A dry run should be performed with the tools that will be used. It is important that a means is provided to reach all glovebox surfaces with the abrasive pad.
- The tools should have grips or a non-slip wrap to prevent them from sliding out of the gloves.
- Spray bottles should be used that can be sprayed while in the horizontal position.
- The glovebox surfaces, including the gloves and doors will become sticky when left overnight.
- One should insure that all surfaces are rinsed thoroughly before stopping work overnight.
- A wet vacuum may be used to speed up the rinsing and drying process, however this will substantially increase the waste volume to be disposed.
- The spray bottles should be checked for clogs before introducing them into the glovebox.
- The alpha probe should be protected while not in use.

Technology Selection Considerations

The following should be considered when selecting acidified cerium nitrate solutions as a decontamination technology.

- The site using the cerium nitrate decontamination technology must have TRU waste disposal capabilities for rags.
- Because the decontamination process can be strenuous, only workers in good health should be used.

APPENDIX A
REFERENCES

Shaw Environmental & Infrastructure, 2002. *Test Plan for Cerium Nitrate Decontamination of Gloveboxes.*

Kaiser Hill, Inc. *Mock-Up Testing of Ce(IV) Decontamination of Raschig Ring Tanks in Building 371.*

U.S. Army Corps of Engineers (USACE), 1996. *Hazardous, Toxic, and Radioactive Waste Remedial Action Work Breakdown Structure*, Prepared for the U.S. Department of Energy, draft January.

APPENDIX B
TECHNOLOGY COST COMPARISON

Basis of Estimated Cost

The implementation activity titles shown in this cost analysis were derived from observation of the work performed and from a reasonable estimate of the level of effort required for implementation at other DOE sites. The activities are grouped under higher level work titles according to the work breakdown structure shown in the HTRW RA WBS (U.S. Army Corps of Engineers 1996). The HTRW RA WBS was developed by an interagency group, and is used in this analysis to provide consistency with the established national standards.

The goal of the demonstration was to reduce residual fixed contamination to a level that would result in a specific activity level below 50 kdpm/100 cm^2. A secondary goal was to determine what lower activity limits were achievable within a reasonable timeframe. This effort was aimed at the possibility of preparing contaminated gloveboxes for reuse in other operations. Additional assumptions are delineated in Section 5 of the main document.

The costs shown in this analysis are computed from observed duration and hourly rates for the crew, supplies, and equipment.

The cost estimate for each technique is based on decontamination of the floor of an operational glovebox at LANL. The overall surface area treated by each technique consisted of approximately 0.52 m^2 (5.6 ft^2) of the glovebox floor. The time intervals for the various tasks performed for the baseline technology were recorded and used to estimate a unit cost for one square meter (m^2).

Activity Descriptions

Mobilization and Preparatory Work (WBS 33.1.01)
Mobilization of Equipment
Mobilization of equipment includes purchasing and preparing the chemical solutions for demonstration. The demonstration used 750 mL (25.4 oz) of solution for each technology to decontaminate one half of the glovebox floor (0.52 m^2 [5.6 ft^2]) during five, 150 mL (5 oz) applications (134 mL/ft^2 [1.4L/m^2]). These numbers were used to calculate the quantity of solution required to decontaminate one square meter of the glovebox floor.

Innovative technology - The cerium nitrate solution was purchased through GFS chemicals at a cost of $50/L ($189.27/gal). Table 3 indicates that 900 mL (0.24 gallon) would be required to decontaminate 0.52 m^2 of the glovebox floor after 6 cycles. Therefore, the total cost of cerium nitrate solution needed to decontaminate the floor is approximately $45.

Baseline technology - The 0.5N nitric acid solution was purchased from Cole Palmer at a cost of $5/L ($18.90/gal). Table 3 indicates that 1350 mL would be required to decontaminate 0.52 m^2 of the glovebox floor after 9 cycles. Therefore, the total cost of nitric acid solution required to decontaminate the floor is approximately $6.75.

Mobilization of Personnel – It was assumed that personnel mobilization began when the equipment and materials (i.e., spray bottles, abrasive pads, polypropylene rags) were placed into the glovebox.

Submittals/Implementation Plans – Plans and permits were assumed to be complete prior to the start of work and were not considered in this cost estimate.

Monitoring, Sampling & Testing (WBS 33.1.02)
The cost estimates for this WBS element included 2 technicians to conduct decontamination operations for both the innovative and baseline techniques. Table B-1 provides a table that shows the recorded times for the decontamination activities associated with the demonstration.

Table B-1
Demonstration Times to Decontaminate a 0.52 m^2 (5.6 ft^2) Glovebox Floor

Activity	Demo Time (min)	Demo Area (m^2)	Min/m^2	Time cerium nitrate [6 cycles] (hr)	Time nitric acid [9 cycles] (hr)
Load materials into glovebox	10	N/A	N/A	1.0	1.5
Apply and scrub	5	0.52	9.62	0.5	0.75
Dry and polish	15	0.52	28.85	1.5	2.25

Glovebox survey times are not typically scalable since the time required for each successive survey is lower due to the ongoing reduction in “hot spots”. This process has been observed in other decontamination demonstrations. While the initial survey of the glovebox floor required 15 minutes to complete, this is about the minimum time required to survey successive hot spots so 15 minutes will be used as the survey time for each cycle.

The estimated survey time for 6 cycles of cerium nitrate technique is 90 minutes (1.5 hr).
The estimated survey time for 9 cycles of nitric acid technique is 135 minutes (2.25 hr).

Decontamination (WBS 33.1.02)
Equipment Decontamination and Release – For this estimate, it is assumed that all equipment used for decontamination will be packaged for disposal instead of being decontaminated.

Waste Disposal (WBS 33.1.18)
Section 3, Performance, subsection Waste Minimization provides a detailed discussion regarding the quantities of waste generated during the demonstration. Table 3 provides the quantities of waste generated during the demonstration and an estimate of the total waste quantity for an entire 7 m^2 (75 ft^2) glovebox. It is assumed that all wastes from this operation will have to be disposed as TRU waste. According to the LANL 2000 Waste Recharge Rates, the cost of TRU waste is \$34,550.00/m^3 (\$978.35/ft^3).

Cost Estimate Summary

The cost analysis details are summarized in Tables B-2 and B-3. The tables break out each member of the crew, each labor rate, and each piece of equipment used.

Table B-2
Cerium Nitrate Implementation Costs

	Labor	Materials	Labor Qty	Units	Unit Cost	Qty	Subtotal
Mobilization and Preparatory Work							**$337.75**
Materials							*$69.00*
		0.25N cerium nitrate		Liter	$50.00	0.9	$45.00
		Rags		Lump Sum			$24.00
Labor							*$268.75*
	Initial glovebox survey		2	Hour	$107.50	0.25	$53.75
	Load materials into glovebox		2	Hour	$107.50	1	$215.00
Monitoring, Sampling & Testing							**$698.75**
Labor							*$698.75*
	Apply and scrub		2	Hour	$107.50	0.5	$107.50
	Dry and Polish		2	Hour	$107.50	1.5	$322.50
	Survey		2	Hour	$107.50	1.25	$268.75
Demobilization							**$3,182.85**
Labor							*$215.00*
	Waste packaging		2	Hour	$107.50	1	$215.00
Waste Disposal							*$2,967.85*
		Disposal cost		Cubic meter	$34,550	0.0859	$2,967.85
TOTAL							**$4,219.35**
Unit costs						**($/m^2)**	**$8,114.13**
						($/ft^2)	**$753.45**

Table B-3
Nitric Acid Implementation Costs

	Labor	Materials	Labor Qty	Units	Unit Cost	Qty	Subtotal
Mobilization and Preparatory Work							**$419.00**
Materials							*$42.75*
		0.5N nitric acid		Liter	$5.00	1.35	$6.75
		Rags		Lump Sum			$36.00
Labor							*$376.25*
	Initial glovebox survey		2	Hour	$107.50	0.25	$53.75
	Load materials into glovebox		2	Hour	$107.50	1.5	$322.50
Monitoring, Sampling & Testing							**$1,075.00**
Labor							*$1,075.00*
	Apply and scrub		2	Hour	$107.50	0.75	$161.25
	Dry and Polish		2	Hour	$107.50	2.25	$483.75
	Survey		2	Hour	$107.50	2	$430.00
Demobilization							**$4,671.95**
Labor							*$215.00*
	Waste packaging		2	Hour	$107.50	1	$215.00
Waste Disposal							*$4,456.95*
		Disposal cost		Cubic meter	$34,550	0.129	$4,456.95
TOTAL							**$6,165.95**
Unit Costs						**($/m^2)**	**$11,857.60**
						($/ft^2)	**$1,101.06**

APPENDIX C
ACRONYMS AND ABBREVIATIONS

Cm	centimeters
cm^2	square centimeters
D&D	Decontamination and Decommissioning
DF	Decontamination Factor
DOE	U.S. Department of Energy
ft	feet
ft^2	square feet
ft^3	cubic feet
HTRW RA WBS	Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure
in	inch(es)
in^2	square inches
ITSR	Innovative Technology Summary Report
kdpm	thousand disintegrations per minute
L	liter(s)
LANL	Los Alamos National Laboratory
LLW	Low Level Waste
LSDDP	Large-scale Demonstration and Deployment Project
m	meters
m^2	square meters
m^3	cubic meters
mL	milliliters
N	normal
MTRU	Mixed TRU waste
OST	Office of Science and Technology
RFETS	Rocky Flats Environmental Technology Site
TA	Technical Area
TRU	transuranic